102 Abdominal Roentgenography

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Definition

Abdominal imaging encompasses a range of techniques for evaluating diseases of the liver, gallbladder, and pancreas as well as identifying the nature and source of gastrointestinal bleeding. *Computed tomography* (CT) is a radiographic technique that employs a computer to construct an image from radiographic attenuation data. *Diagnostic ultrasound* is a noninvasive imaging modality that uses high-frequency sound waves to generate images of the body. *Magnetic resonance imaging* (MRI) utilizes the physical principles of nuclear magnetic resonance to image the body. With *radionuclide imaging,* detection of the gamma radiations emitted from the site or sites of localization provides functional information about the organ or system. *Double contrast barium studies* use a combination of air and barium contrast medium to identify lesions as small as 2 to 3 mm.

The indications for these techniques and their variations depend on the particular problem being investigated and are discussed in the Clinical Significance section.

Technique

Computed Tomography

CT examinations should be performed before any radiographic study requiring barium, unless the reasons for scheduling the CT examination are dependent on the result of the barium study. Barium contrast will cause artifacts and significantly degrade the image, especially if the intestinal barium collection is large. Patients should only have clear liquids for 4 to 8 hours prior to the CT scan. When scanning the abdomen and pelvis, it is absolutely essential that the gastrointestinal tract be opacified. This step is necessary because unopacified bowel can mimic lymph nodes, malignant masses, or abscesses. Indeed, the most common error in body CT scanning is failure to give adequate amounts of oral contrast material to identify the alimentary tract correctly. Opacification of the GI tract is usually accomplished by oral and occasionally rectal administration of a 2% solution of iodinated contrast or a very dilute (2%) solution of barium. Intravenous contrast material identical to that used for intravenous pyelography greatly assists interpretation, not only by opacifying normal vascular structures but by making nonenhancing masses more apparent. Contrast-enhanced CT, particularly when given as a bolus with multiple, rapid, sequential, "dynamic" scans (seven 2-second scans per minute) provides a good estimate of tissue or tumor vascularity.

Radiation exposure from CT scanning is small and compares favorably with conventional imaging modalities. An average abdominal scan delivers a maximum surface dose of 1 rad while the internal organ dose will be smaller. This is equivalent to 1 minute of fluoroscopy or one-third to one-fifth the radiation exposure of a standard radiographic study such as barium enema or excretory urogram.

Ultrasound

Unlike a chest film, excretory urogram, or barium enema, which is performed in a standard fashion, ultrasound is very much a problem-oriented imaging technique. Excellent communication between the clinician and radiologist is essential to tailor and direct the appropriate examination to the patient's specific problem.

Sonography not only provides information concerning the location, nature, and size of internal structure, but can do this independent of organ function, without ionizing radiation or contrast media. Studies can be performed quickly and safely, with a minimum of patient preparation and cooperation. The studies can be performed at the patient's bedside. Studies to date have determined no untoward effects of ultrasound on mammalian tissues at the intensity used in diagnostic sonography. Indeed, ultrasound examination of the fetus is a routine procedure.

Magnetic Resonance Imaging

Few developments in radiology have caused as much excitement and anticipation as MRI because it combines the advantages of the other imaging modalities without sharing their disadvantages. MRI offers superb tomography with excellent spatial resolution like CT, it offers the possibility of following metabolic processes and physiology like nuclear medicine, and it affords tissue information without radiation like ultrasound. Also, MRI does not have any known biologic ill effects.

Contraindications to this procedure include pacemakers, metallic implants in the head, critically ill patients who need life support systems (metallic objects must be kept away from this very powerful magnetic field), and claustrophobia.

Radionuclide Imaging

Radionuclide imaging has become quite sophisticated in the last several years. A large variety of radiopharmaceuticals and an increasing awareness of pharmacokinetics in normal and disease states have increased the number of clinical applications. Because nuclear imaging utilizes organ- or system-specific pharmaceuticals, the technique is superior for study of function. In most instances, however, the structural or anatomical information provided by nuclear studies is inferior to that of standard radiography, CT, MRI, and ultrasound.

Double Contrast Barium Studies

Double contrast studies of the esophagus, stomach, duodenum, small bowel, and colon have dramatically improved the sensitivity and accuracy of radiology in the detection of gastrointestinal abnormalities. Air is administered per rectum on colon studies and 5 g of effervescent granules that produce 300 to 500 cm^3 of carbon dioxide are ingested orally to distend the stomach. Lesions can be seen in profile at the outer surface of the gut but can also be visualized through the lumen itself. Small lesions are "painted" with barium and not obscured by large amounts of barium. Thus 2 to 3 mm polyps, erosions, and aphthous ulcers can be detected.

Small bowel enteroclysis has gained popularity for the evaluation of chronic gastrointestinal bleeding when routine barium and endoscopic studies are negative. Following the peroral placement of a tube into the distal duodenum, large volumes of barium are rapidly instilled with or without double contrast techniques. Tumors and inflammatory diseases of the small bowel that are not detected on the small bowel follow-through series may be identified by enteroclysis.

Basic Science

While the x-rays of standard radiography are detected by film, in *CT* the x-ray photons strike radiation detectors that produce a minute electrical impulse proportional to the intensity of the x-ray beam. The electrical current is quantified numerically and registered in the form of computer stored data. A visual display is produced by the assignment of varying shades of gray to the individual picture elements of a cathode ray tube monitor according to their relative attenuation values. CT images can be re-created and manipulated by the computer to highlight certain density differences and can be reformatted to give images in the sagittal, coronal, transverse, or oblique plane. CT has exquisite density discrimination, which accounts for its ability to detect lesions as small as 3 to 5 mm.

Ultrasound scans are obtained by placing a transducer, which is both a sound generator and a sound receiver, on the skin over the region of interest and directing a narrow acoustic beam into the body. As the sound beam passes through tissue, part of the sound is absorbed and part is reflected at the interfaces between tissues of different acoustic impedance (acoustic impedance is the product of the density of the tissue and the velocity of sound passing through it). The image is formed by collecting these returning echos and displaying their position and intensity on a cathode ray tube. The echo pattern of a tissue depends upon the homogeneity of the cellular elements and their acoustic impedances. The more nonhomogeneous a tissue, the greater the variety of acoustic impedances and the greater the internal echos; the more homogeneous a tissue, the more uniform the acoustic impedance so that fewer echos are created. Therefore, fluid-filled cysts that have homogeneous content will generate few or no internal echos, whereas fat, with many cellular elements, will produce many. The characteristic echo pattern of a tissue can be altered by the influx of fluid, cellular infiltrates, tumor, or fibrosis, and these changes as well as alteration in organ size form the basis of sonographic detection of disease.

MRI does not use ionizing radiation but depends upon a strong magnetic field, between 1,000 and 15,000 gauss (0.1 to 1.5 tesla), and radiofrequency pulses in the range of 15 to 60 MHz. (The earth's magnetic field by comparison is 0.5 gauss.) When placed in a strong magnetic field, certain nuclei in the body, such as hydrogen, phosphorus, and sodium, will become aligned with the magnetic field. These nuclei are then perturbed by the application of short radiofrequency pulses. The nuclei temporarily lose their orientation with the magnetic field, and as they become realigned, they give off radiofrequency energy that is detected by antennas within the magnet. A computer then determines the location and intensity of these radiofrequency pulses and from these data constructs an image. Images may be obtained in any plane.

Since the body is composed primarily of water, hydrogen is the most important nucleus imaged by MRI. Most pathologic processes alter not only the amount of intracellular water but its type: water tightly bound to proteins, loosely bound to proteins, and "free" water within the cytoplasm of the cell. These subtle changes of intracellular water are the basis for the detection of disease with MRI. At higher magnetic field strengths (>1.5 tesla), nuclei of the body such as sodium and phosphorus can be imaged and spectroscopy performed. This permits detection of pathology before macroscopic and even microscopic changes of morphology occur.

While conventional radiography and CT depend upon transmitted x-rays produced by an x-ray tube, *nuclear imaging* examinations depend on emitted gamma rays from *in vivo* radiopharmaceuticals previously delivered parenterally or orally. Tracer localization may occur by one or more metabolic or physical mechanisms: active transport, phagocytosis, cell sequestration, capillary blockage, simple or exchange diffusion, compartmental localization, and antigen–antibody reaction. The most common isotope used in abdominal imaging is technetium-99m (^{99m}Tc), which can be bound to many chemicals whose structures will determine the *in vivo* distribution of this chemical complex.

In conventional single contrast barium studies, lesions are detected only by deforming the outer contour of the barium column. Small lesions are obscured by a "sea" of intervening barium. In air contrast studies, a small amount of thick barium is given in order to coat the mucosal surface of the gut and then gas is given to distend the lumen. This is the principle underlying the *double contrast barium study*.

Clinical Significance

During the past decade, abdominal imaging has been revolutionized by the development and implementation of new technologies and by technical improvements and more widespread use of established methods. The plethora of new and constantly evolving techniques often confronts the clinician with a tantalizing, albeit expensive choice in the work-up of patients. Appropriate application of these imaging modalities to major abdominal problems depends on taking an algorithmic approach to specific problems.

Jaundice

Careful history and physical examination combined with routine liver function tests will suggest the etiology of hyperbilirubinemia in most patients with jaundice. In 20 to 40% of patients, however, the clinical distinction between diffuse parenchymal disease, focal liver disease, and extrahepatic biliary obstruction is not possible. A number of invasive (ERCP and PTC; see below) and noninvasive (CT and ultrasound) modalities are available for evaluation of the jaundiced patient (Fig 102.1).

Obstructive Jaundice. Early recognition of jaundice caused by extrahepatic biliary obstruction is important because prolonged obstruction may lead to deterioration of liver function, recurrent bouts of cholangitis and sepsis, and occasionally hepatic abscess formation. For these reasons, ultrasound and/or CT is recommended in all patients suspected of having obstructive jaundice (Ferrucci et al., 1983). Indeed, these low-risk, high-yield, noninvasive techniques can detect segmental biliary dilation or early dilation of extrahepatic bile ducts in patients with elevated alkaline phosphatase but normal bilirubin levels.

Ultrasound should be the initial screening procedure in patients with suspected obstructive jaundice because it is rapid, safe, and readily available and has a 97% accuracy in detecting obstruction (Ferrucci et al., 1983). Dilated intrahepatic ducts appear as branching tubular structures running adjacent to portal venous structures. Extrahepatic obstruction is diagnosed when the common hepatic duct anterior to the portal vein is larger than 4 to 5 mm. If a mass is demonstrated, sonographically guided aspiration biopsy can be performed. Ultrasound is superb in the diagnosis of cholelithiasis and somewhat less sensitive in the diagnosis of choledocholithiasis. Unfortunately, bowel gas or body habitus makes evaluation of the distal common bile duct difficult in some patients. If the etiology and level of obstruction are not apparent, computed tomography is recommended.

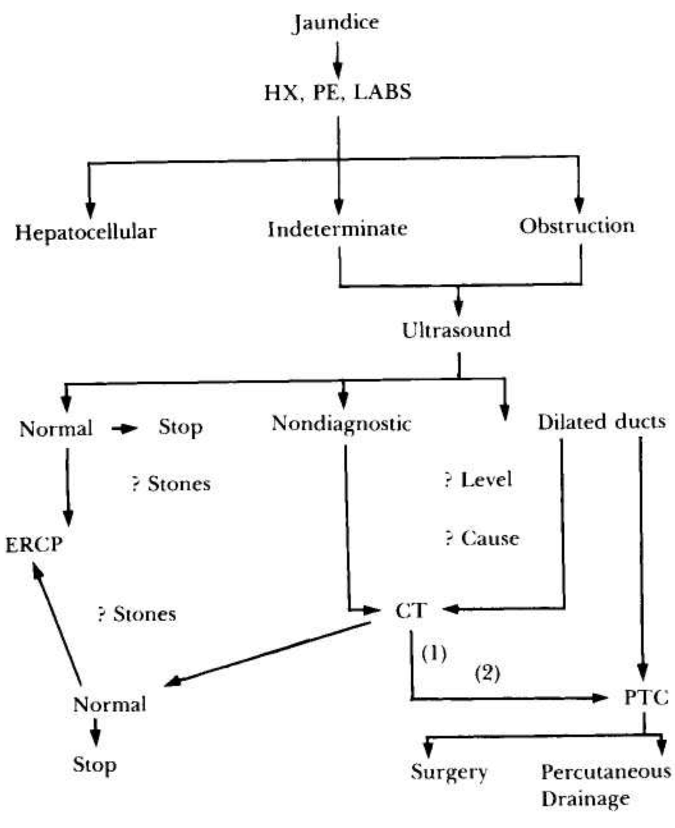

Figure 102.1
Algorithm for radiological work-up of jaundice. If CT shows obstruction, do PTC prior to drainage. If PTC shows a malignant-appearing lesion, do CT to stage.

The sensitivity of computed tomography (CT) (96%) in detecting biliary obstruction is comparable to that of ultrasound (97%), but it is not recommended as a screening tool because it is much more expensive, less available, and more time consuming, and it uses ionization radiation (Baron et al., 1982). When the intrahepatic and extrahepatic ducts are well seen sonographically and are normal in caliber, no further radiologic evaluation is needed in most patients. CT plays a major role in patients in whom sonography indicates ductal dilation but does not clearly establish the level and cause of obstruction. CT should be the initial imaging procedure in obese patients and those with primary biliary–enteric anastomoses, as these patients will often have an unsatisfactory ultrasound study.

CT provides an unrivaled look at the porta hepatis and pancreas and has a 93% accuracy in detecting the level of biliary obstruction (vs. 43% for ultrasound) and an 82% accuracy in determining its etiology (vs. 30% for ultrasound) (Baron et al., 1982). The CT diagnosis of biliary obstruction is based on demonstrating dilation of the intrahepatic or extrahepatic bile ducts, or both. Dilated intrahepatic ducts appear as linear, branching, or circular structures of near water density that enlarge as they approach the porta hepatis. Computed tomography has an 80% accuracy in detecting choledocholithiasis and often obviates the need for more invasive diagnostic procedures in patients with obstructive jaundice due to stone disease. If a mass causing the obstruction is identified, an aspiration biopsy under CT guidance can be performed. If the offending lesion is a tumor, it can be staged by CT, since retroperitoneal and mesenteric adenopathy as well as hepatic and adrenal metastases are readily diagnosed by this modality.

If ultrasound reveals dilated ducts and no gallbladder calculi, CT is usually effective in finding the cause of extrahepatic biliary obstruction. If CT demonstrates no lesions, then invasive studies are indicated. It has been suggested that endoscopic retrograde cholangiopancreatography (ERCP) be performed in patients without intrahepatic duct dilation and that percutaneous transhepatic cholangiography (PTC) be attempted first in patients who have such dilation. While it is true that PTC is successful in opacifying only 75% of nondilated ducts, other considerations such as potential interventional procedures should be kept in mind (Ferrucci et al., 1983). The choice between ERCP and PTC should be made on the basis of the provisional diagnosis as established from all data available up to that point. If a stone in the common bile duct is likely, ERCP should be performed for confirmation and for removal by endoscopic papillotomy. If a malignant cause of biliary obstruction is likely, then PTC, which may guide temporary or permanent biliary drainage, is preferred. In the event either technique fails, the other will serve as a backup.

ERCP has several unique advantages including endoscopic visualization of the intestine, visualization of the lower portion of a completely obstructed common bile duct, evaluation of a nondilated intrahepatic system (e.g., sclerosing cholangitis), and delineation of the pancreatic duct.

The *intravenous cholangiogram* has little role in the modern diagnostic scheme. The distal portion of the common bile duct is not well visualized even with routine tomography, and the biliary tree is poorly opacified when the serum bilirubin level is over 3 mg/dl or serum alkaline phosphatase is rising. Also, reactions to the contrast medium are more frequent with intravenous cholangiography than with any other radiologic contrast agent. It is a very poor alternative to PTC or ERCP.

Hepatobiliary Scintigraphy. ^{99m}Tc HIDA, performed with the newer analogues of ^{99m}Tc-labeled iminodiacetic acid derivatives, permits visualization of the biliary tree when the serum bilirubin is high (10 to 15 mg/dl). A satisfactory radionuclide study will show the size of the common bile duct and the dynamics of excretion into the duodenum. This examination, however, does not identify the cause of obstruction and should be used only as a backup procedure in the rare instances in which ultrasound, CT, PTC, and ERCP fail to solve the diagnostic problem. It is useful in childhood jaundice and in the diagnosis of obstructed biliary–enteric anastomoses.

Nonobstructive Jaundice. The ability of CT and ultrasound to characterize diffuse parenchymal disease has not yet matched the exquisite accuracy of these modalities in detecting obstructive jaundice. CT can accurately depict liver size, fatty infiltration, hemosiderosis, and copper deposition, and strongly suggest the diagnosis of cirrhosis by demonstrating signs of portal hypertension (e.g., ascites, peritoneal and retroperitoneal varices, and changes in liver size). Ultrasound has an 80% accuracy in detecting diffuse parenchymal disease, and the diagnosis of cirrhosis can be suggested by demonstrating varices, recanalization of the portal vein, and relative preservation of caudate lobe size in the presence of right lobe atrophy (Berland, 1984). The radionuclide ^{99m}Tc–sulfur colloid liver-spleen scan is still the most sensitive noninvasive means of demonstrating hepatic parenchymal disease.

In patients with icterus due to primary and secondary neoplasms causing hepatic replacement or segmental biliary obstruction, CT, ultrasound, ^{99m}Tc–sulfur colloid scan, and MRI are sensitive diagnostic tools.

Liver Metastases

The diagnosis of hepatic metastases is a common clinical problem that has significant prognostic and therapeutic implications. Choosing a method to examine the liver depends on the anticipated benefits of detecting and specifying the disease as well as available technology, expertise, delays in scheduling, risks, and expense. CT, ultrasound, nuclear medicine, and MRI are all useful in this regard. The question naturally arises as to which technique should be used as a screening tool. Despite the obvious clinical importance of this subject, there have been few good prospective studies comparing the sensitivity and specificity of CT, MRI, ultrasound, and hepatic scintigraphy in the detection of hepatic metastases.

Scintigraphy using ^{99m}Tc-labeled sulfur colloid is a quick, low-risk procedure that is less operator dependent than other radiographic approaches to suspected hepatic metastases. This radiopharmaceutical is phagocytized by the reticuloendothial system of the liver, spleen, and bone marrow. Normal-functioning liver and spleen tissue appear as radioactive "hot" areas, whereas "cold" areas lack functioning reticuloendothial tissue. Any space-occupying lesion that replaces or displaces normal Kupffer cells will appear as holes or cold spots. The major drawback of this modality is its lack of specificity: metastases, cysts, abscesses, and hepatomas all have a similar appearance. Also, radionuclide scanning will not detect lesions less than 2 cm that are deeply seated in the substance of the liver. *Ultrasound* is a more specific and accurate method and does not utilize ionizing radiation. Metastases may appear as heperechoic, hypoechoic, or complex lesions or may have a target appearance (Figure 102.2). These abnormalities are not pathologically specific. Ultrasound is exquisitely operator dependent and may be limited by body habitus and bowel gas.

CT detects hepatic metastases by virtue of their low at-

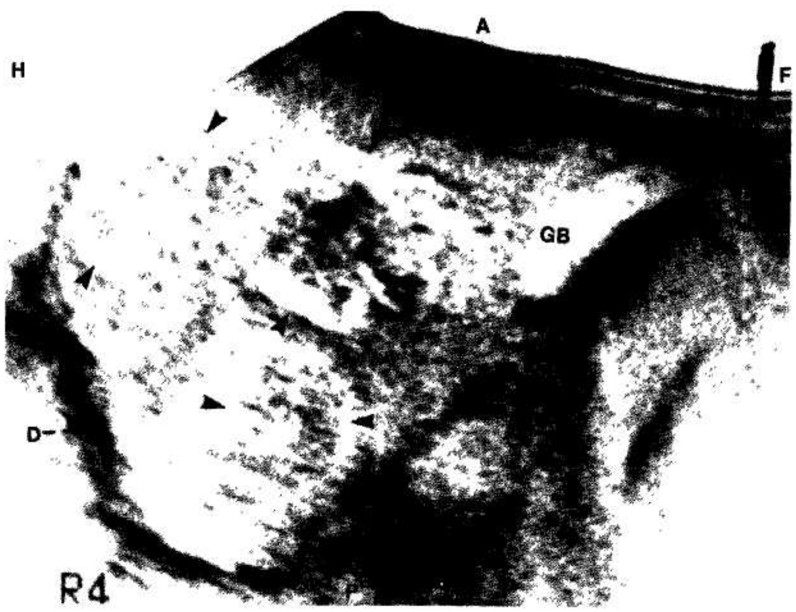

Figure 102.2
Longitudinal ultrasound scan of the liver obtained 4 cm to the right of the midline in a patient with metastases (arrowheads) from breast cancer. GB = gallbladder, A = anterior, P = posterior, D = diaphragm, H = toward head, F = toward feet.

tenuation when compared to normal hepatic parenchyma (Figure 102.3). Intravenous contrast material usually exaggerates the differences in density between mass lesions and surrounding parenchyma. Metastases have a lower density than normal parenchyma and are more dense than cysts. Metastases are also less well circumscribed and less uniform in density than cysts.

The literature suggests that CT should be the first choice for examining patients with suspected metastatic liver disease (Bernardino, 1982). This is based on the greater sensitivity and specificity of contrast-enhanced CT when compared to sonography and scintigraphy in focal liver disease, the ability of CT to detect diffuse liver abnormalities, the greater ease of standardizing the CT examination and interpretation, the ability of CT to predict the histology of many focal and diffuse liver diseases accurately, and the superiority of CT in defining and characterizing extrahepatic abnormalities (e.g., adrenal metastases) in patients with malignancies.

Ultrasound may be done first when fast CT scanners (<5 sec) are not available, when intravenous contrast cannot be administered, when other problems arise with technique, for patients requiring sonography for other reasons, or when delays for scheduling CT scans are too long. Radionuclide liver–spleen scanning should play a very limited role in the early evaluation of liver disease, being reserved for occasionally clarifying the presence of diffuse liver disease or for patients difficult to study by either CT or sonography (Gore et al., 1982). MRI has evolved into a competitive modality for the detection and characterization of liver metasteses. Some reports claim its superiority in this regard, but its expense and lack of availability still militate against its routine use for screening (Heiken et al., 1989).

Disorders of the Gallbladder and Biliary Tract

Approximately 20 million people in the United States have *gallstones*. Indeed, 600,000 cholecystectomies are performed annually, making this the most common abdominal surgical procedure. For every patient who eventually undergoes cholecystectomy, an estimated two to five patients have right upper quadrant pain that requires gallbladder imaging for gallstones. Four modalities are currently available for evaluation of the gallbladder: the oral cholecystogram (OCG), ultrasound, CT, and ^{99m}Tc HIDA cholescintigraphy (Berk, 1981).

With *OCG*, the patient consumes 3 g of iapanoic acid (Telepaque), an iodinated agent that is absorbed in the small bowel, conjugated in the liver, excreted in the bile, and concentrated in the gallbladder. The following day, multiple radiographs of the gallbladder are obtained. Although OCG has an accuracy of 90%, it has several major limitations. Peak gallbladder opacification occurs within 14 to 19 hours so it is not suitable for patients who present with acute right upper quadrant pain. A "double" dose examination is required in 15 to 25% of normal patients, necessitating prolonged hospitalization or a return visit. Ionizing radiation is used, and some patients develop diarrhea from the contrast tablets. Also, many factors unrelated to gallbladder function, such as malabsorption, poor liver function, or biliary obstruction, will interfere with the examination.

Although OCG has been the gold standard for decades, it has been largely supplanted by *ultrasound*, which is now the imaging modality of choice for the diagnosis of disorders of the gallbladder and biliary tract. The advantages of ultrasound include: (1) rapid diagnosis of gallstones (15 minutes vs. 16 hours for OCG), (2) absence of ionizing radiation

Figure 102.3
Nonenhanced CT scan of the upper abdomen in a patient with malignant ascites (A) and liver metastases (arrows) from colon cancer. S = contrast filled stomach, LS = fluid in lesser sac, SP = spleen, P = pancreas, K = kidney.

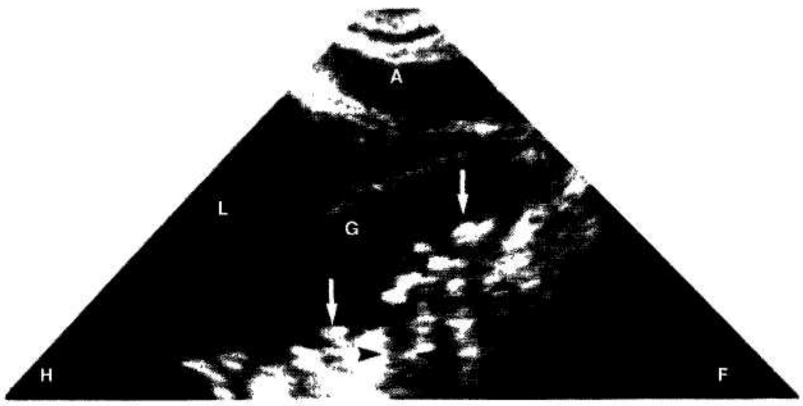

Figure 102.4
Longitudinal scan of the gallbladder (G) demonstrates multiple stones (arrows) that cast an acoustic shadow (arrowheads). L = liver, H = toward head, F = toward feet, L = liver, A = anterior.

(3) absence of side effects of contrast medium, and (4) ability to perform the study in the presence of various disorders (e.g. liver disease, jaundice, malabsorption, pancreatitis, and pregnancy).

Sonographically, gallstones produce echogenic foci within the gallbladder, show movement with change in position, and produce a posterior acoustic shadow (Figure 102.4). The shadow is produced because the gallbladder absorbs most of the sound beam and converts it into heat. Therefore, no sound is available to interrogate deeper structures and thus the shadow is formed. All three conditions must be fulfilled to make the diagnosis of gallstones. Meticulously performed real time sonography can detect calculi as small as 1 mm and has a sensitivity reported as high as 98% (Laing et al., 1981).

The gallbladder, which can be identified in 95% of fasting patients, appears as a saccular, anechoic structure in the region of the interlobar fissure of the liver (Laing et al., 1981). Ideally the patient should be fasting 8 to 12 hours to allow for maximum filling and distention of the gallbladder. The patient, of course, can be scanned at any time. Failure of ultrasound to identify the gallbladder in the fasting patient usually indicates a shrunken or stone-packed organ.

When the gallbladder is studied, the common hepatic duct can be visualized anterior to the portal vein. In the normal patient the duct is 4 to 5 mm or less. If the patient has had a cholecystectomy, the common hepatic duct can increase to 7 mm in size; in most patients it remains 4 mm or smaller. The gallbladder wall thickness is also assessed; it is normally less than 2 mm in size. It can be thickened in a variety of conditions including acute and chronic cholecystitis, ascites, total parenteral nutrition, portal hypertension, leukemia, and lymphoma.

Tiny stones or biliary sludge (comprising cholesterol crystals and calcium bilirubinate granules) produce a fine echogenic pattern in the gallbladder without shadowing. This occurs when there is biliary stasis, for example, in patients who are fasting, on total parenteral nutrition, or have had recent surgery. This echogenic material layers in the dependent portion of the gallbladder.

If a calculus becomes impacted near the neck of the gallbladder or in the cystic duct, the patient will experience biliary colic and ultimately *acute cholecystitis.* There is currently a controversy in radiology as to the preferred technique for the diagnosis of acute cholecystitis. Two modalities are of great value in evaluating these patients: cholescintigraphy and ultrasound (Figure 102.5). *Ultrasound* will demonstrate gallstones and occasionally thickening of the gallbladder wall. The demonstration of pericholecystic fluid is most suggestive of this diagnosis but is an uncommon finding. There is also the sonographic Murphy's sign, in which the gallbladder is exquisitely tender when the transducer is passed over it. The absence of this sign is especially

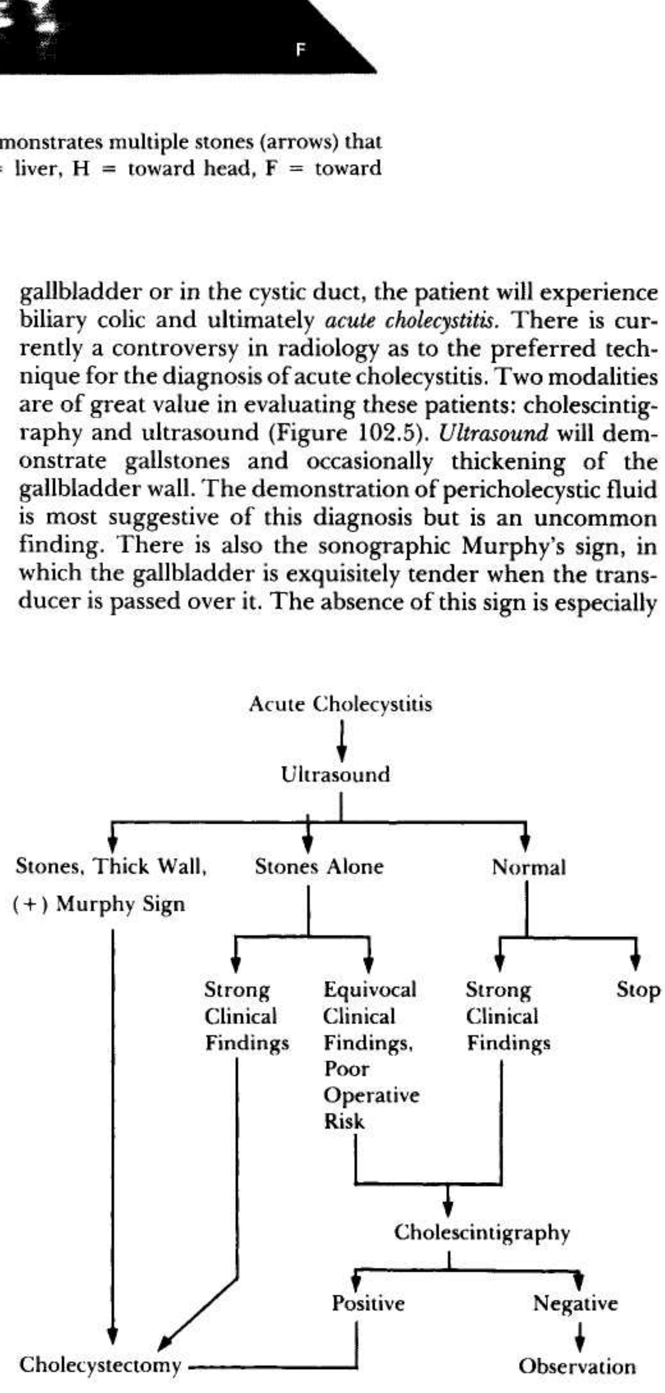

Figure 102.5
Algorithm for radiological work-up of acute cholecystitis.

useful if the tenderness arises from an adjacent structure such as the right kidney or gastric antrum. Even lacking these specific features to suggest acute cholecystitis, one need not prove that the cystic duct is obstructed to justify cholecystectomy in a patient with typical pain and gallstones (Laing et al., 1981).

The *HIDA gallbladder scan* is another excellent modality for the diagnosis of cholecystitis. It is performed after the intravenous injection of tagged compounds that are cleared and rapidly excreted by hepatocytes into the biliary tree. The isotope fills the gallbladder by retrograde passage through the cystic duct and then enters the duodenum via the common duct. Normally the gallbladder and duodenum are filled by radioisotope in 1 hour or less. If the gallbladder is visualized, cystic duct patency is assured and the likelihood of acute cholecystitis is small. The modality has several drawbacks, however. First, stones within the gallbladder cannot be visualized. Second, failure to visualize the gallbladder is suggestive of acute cholecystitis but does not prove the diagnosis. The gallbladder of patients who have a history of alcoholism or pancreatitis, are on total parenteral nutrition, or have been fasting for prolonged periods may fail to opacify. Additionally, the HIDA scan visualizes only the hepatobiliary system and does not provide a view of surrounding structures. Ultrasound affords visualization of the pancreas, liver, and right kidney, all of which may simulate the pain of acute cholecystitis. This is important to consider in view of the fact that only one-third of the patients with symptoms typical of acute cholecystitis have the disease.

For these reasons, ultrasound is recommended as the initial imaging procedure for the gallbladder. If it demonstrates stones and the clinical history is characteristic, then cholecystectomy can be performed. If, however, the patient's clinical condition is a relative contraindication to emergency surgery, further proof that the patient's signs and symptoms are due to cystic obstruction should be obtained with the HIDA scan.

Diseases of the Pancreas

Traditional radiographic techniques such as plain films and barium studies image the pancreas only indirectly. Indeed, the pancreas has long been considered the "hidden" organ of the abdomen, difficult to examine both clinically and radiographically. The development of CT and ultrasound has opened up new frontiers in the noninvasive detection of pancreatic and peripancreatic lesions by allowing direct visualization of the pancreatic parenchyma (YanKaskas et al., 1985). ERCP is a very useful diagnostic adjunct in this regard.

Pancreatitis is a very common clinical entity that is associated with considerable morbidity and mortality. Alcoholism, common bile duct stones, trauma, drugs, hyperlipidemia, and pancreas divisum may precipitate the disease. The spectrum of clinical presentations is broad: from acute epigastric pain with nausea and vomiting indicative of acute pancreatitis, to fever and septicemia indicating pancreatic abscess, to shock and intestinal hemorrhage associated with hemorrhagic pancreatitis and bowel necrosis, to chronic pain and severe steatorrhea and malabsorption indicative of pancreatic insufficiency. In acute self-limited pancreatitis, pancreatic imaging is probably not necessary. There are a number of complications of pancreatitis that must be diagnosed for optimal patient management. These include pancreatic fluid collections and pseudocysts, phlegmon, pancreatic abscess, arteriovenous fistulas, biliary obstruction, and hemorrhage. Pancreatic imaging is very important in all these clinical settings in order to determine whether the pancreas is the source of symptoms and to determine the extent of complications.

Acute pancreatitis, regardless of its cause, is associated with edema that causes enlargement, irregularity, and diffusely decreased echogenicity of the pancreas on ultrasound. In acute uncomplicated pancreatitis the pancreas is enlarged and has a low density on CT. The choice between CT and ultrasound in imaging acute pancreatitis is dictated by the expertise of the examiner and the equipment available. Many patients with acute pancreatitis may have an ileus which will preclude thorough sonographic evaluation. CT has the additional ability to image the tail of the pancreas, the lesser sac, and the various peritoneal compartments. This is important in defining the true extent of fluid collections and pseudocysts. CT is also preferred in the imaging of pancreatic abscesses, not uncommon complications of the disease. For these reasons, CT is the best single imaging modality in the diagnosis of pancreatitis and its complications (Williford et al., 1983). Ultrasound, however, can be used to follow the size of a pseudocyst and should by all means be employed to evaluate the gallbladder for gallstones, a major cause of pancreatitis in the United States.

Complications of acute pancreatitis are common and, if detected early, often can be treated without sequelae. This is the primary role of cross-sectional imaging in the disorder.

Intrahepatic or extrapancreatic fluid collections occur in up to 50% of patients with pancreatitis (Figure 102.6). Although the term *pseudocyst* implies the presence of a wall or containing structure, these fluid collections are often uncontained and poorly circumscribed. The fluid collections are rich in proteolytic enzymes and most frequently are found in the lesser sac but may extend along the retroperitoneal tissue planes in any direction. They may also dissect up into the mediastinum and reach the neck or down the retroperitoneum as far as the groin. The wall of the pseu-

Figure 102.6
CT scan of the upper abdomen demonstrates multiple pseudocysts (C) in this patient with pancreatitis. L = liver, K = kidney, V = inferior vena cava, A = aorta with intimal calcification.

docyst is initially formed by whatever tissue structures first limit its spread. As the pseudocyst matures, the evoked inflammatory reaction encapsulates the contents of the pseudocyst with granulation tissue and ultimately with a fibrous wall. On ultrasound, pseudocysts are typically round, smooth cystic collections that can be detected with an accuracy between 50 and 100%. On CT, pseudocysts may first have a soft tissue density that might better be termed "phlegmon," a boggy, edematous pancreas. With maturation, it becomes lower in density. CT is the preferred modality for pseudocysts because it can detect them in extrapancreatic locations and is not hindered by bowel gas. A pseudocyst should be followed until resolution is demonstrated.

Pseudocysts are dynamic lesions that can increase or decrease in size over several days or remain stable for months. In the first 3 weeks 20% will resolve spontaneously, but as chronicity sets in, spontaneous resolution is much less likely and the rate of complications rises to 75% by 13 to 18 weeks. These complications include infection, intraperitoneal rupture, and erosion into adjacent arteries with gastrointestinal hemorrhage or occlusion of the splenic vein.

Pancreatic abscess is another common and serious complication of acute pancreatitis, occurring in up to 40% of patients with hemorrhagic or necrotizing pancreatitis and 2 to 6% of all patients with pancreatitis. If untreated, mortality reaches 100%. CT is the preferred imaging modality in the diagnosis of abscess. It is usually diagnosed by seeing gas within the pancreatic bed.

The diagnosis of *chronic pancreatitis* is suggested by previous attacks of pancreatitis with recurrent pain, steatorrhea, malabsorption, and diabetes, weight loss, and abdominal pain. On ultrasound, the disorder may have a variety of presentations, but often the gland will be small and have increased echogenicity. Sometime these calcifications will cast an acoustic shadow. CT is the preferred modality because it can more readily identify subtle calcifications and abnormal ductal anatomy. More importantly, CT can help differentiate between pancreatic malignancy and chronic pancreatitis. ERCP is another useful diagnostic technique because it has a high degree of accuracy in detecting the changes of chronic pancreatitis and is the best way to evaluate the ductal system in the event that surgical drainage is comtemplated or partial pancreatectomy is indicated.

Carcinoma of the pancreas remains an elusive tumor because exocrine pancreatic neoplasms present with nonspecific symptoms. Carcinoma of the pancreas is now the fifth most common cause of cancer death in the United States. Five-year survival is a dismal 1%; cures are rare because the tumor is seldom diagnosed prior to extensive local growth or metastatic spread.

With the advent of *CT*, pancreatic carcinoma can be diagnosed, resectability determined, and histologic confirmation obtained on an outpatient basis without resorting to laparotomy. The overall accuracy of CT in detecting pancreatic carcinoma is high, ranging from 88 to 94%. CT has established itself as the primary screening modality for pancreatic tumors.

The CT diagnosis of pancreatic carcinoma is based on gross alterations in the size and shape of the gland and identification of disease spread to peripancreatic vascular and nodal structures. Two-thirds of carcinomas appear in the pancreatic head with the remainder occurring in the body and tail. The CT findings in pancreatic carcinoma (Figure 102.7) include pancreatic mass (95%), low attenuation seen within the mass (75%), celiac and superior mesenteric artery encasement by tumor (60%), dilation of the pancreatic duct (50%), biliary dilation (38%), hepatic metastases (30%), and atrophy of the pancreatic tail (20%). Tumors of the body and tail are often larger than those in the head at the time of initial evaluation because they have been asymptomatic for a longer period.

Figure 102.7
CT scan of the upper abdomen shows a large, predominately low-density pancreatic carcinoma (arrows). G = gallbladder, L = liver, S = spleen, K = kidney, A = aorta, C = inferior vena cava.

When no mass defect or contour abnormalities are identified, secondary signs of tumor may be helpful in reaching the diagnosis. Small tumors of the head may produce no contour defects, yet cause dilation of the biliary tree and pancreatic duct. In the absence of calculi, the dilation is often associated with carcinoma of the pancreatic head. In most cases, by the time the diagnosis of carcinoma is made, the tumor is unresectable.

In order to eliminate the need for exploratory laparotomy, tumor resectability must be assessed and tissue confirmation obtained. The primary CT criteria of unresectability are: hepatic or regional lymph node metastases; retroperitoneal extension of tumor enveloping the superior mesenteric artery, splenic vein, celiac artery, or inferior vena cava; loss of the posterior fat planes that separate the pancreas from retroperitoneal lymph nodes; and invasion of contiguous organs. Secondary signs include ascites, splenomegaly due to splenic vein occlusion, and mesenteric varices due to obstruction of the superior mesenteric vein.

CT-directed fine needle aspiration biopsy is an effective means of establishing the histologic diagnosis of carcinoma of the pancreas. In one series an accuracy of 88.7%, a sensitivity of 86%, and a specificity of 100% was reported (Hessel et al., 1982). This technique usually obviates the need for exploratory laparotomy, resulting in a considerable savings of money and patient discomfort in a disease with a 1% survival after 5 years for those who receive operation (Gore et al., 1982).

Carcinoma of the pancreas usually presents as a mass with low-amplitude echos on *ultrasound*. Abnormalities of the pancreas are discerned by noting a change in the typical echogenic texture as well as perception of a bulge in the contour of the gland. Small focal carcinomas that have not changed the boundaries of the gland may be missed. Neither CT nor ultrasound is routinely able to detect the very early carcinoma of the pancreas when it is asymptomatic and curable. Another difficulty is the fact that focal enlargement of the pancreas can be seen with both tumor and pancreatitis. The distinction cannot be made by either modality unless there are ancillary findings of neoplasm such as adenopathy, hepatic metastases, or direct invasion of tumor around the vessels so characteristic of carcinomatous extension.

While both ultrasound and CT have proven quite useful in the evaluation of pancreatic pathology, CT scanning is more reliable and should be the initial imaging procedure when there is suspicion of pancreatic carcinoma.

Angiography and ERCP continue to play an important but diminished role in the diagnosis of pancreatic carcinoma. ERCP is useful when the CT findings are normal or equivocal in a patient with a high index of suspicion for carcinoma. Indeed, ERCP is probably the most accurate and sensitive means of detecting small pancreatic tumors. Also, when CT is equivocally abnormal without ancillary findings of tumor, ERCP may assist in confirming the diagnosis (Gore et al., 1982).

Gastrointestinal Hemorrhage

The expeditious work-up of a patient with gastrointestinal bleeding is essential because it may be the presenting sign for a gastric or colonic neoplasm and because there is an 8 to 15% mortality rate for patients who present with acute gastrointestinal hemorrhage. The extensive gamut of common and uncommon causes for upper and lower gastrointestinal hemorrhage may be evaluated by a variety of imaging techniques such as barium contrast studies, fiberoptic endoscopy, radionuclide scans, and arteriography. A rational diagnostic approach to this complex problem involves a series of decisions based on the clinically suspected origin of bleeding as well as the severity of hemorrhage. No simple, single schema can be applied to the gastrointestinal tract as a whole.

Acute gastrointestinal hemorrhage. Prevailing medical opinion favors *endoscopy* as the initial diagnostic procedure in patients with massive upper gastrointestinal bleeding (Steer and Silen, 1983). The endoscopist can visualize superficial mucosal lesions such as esophagitis, gastritis, superficial duodenal and gastric erosions, as well as Mallory–Weiss tears, varices, and ulcers. Endoscopy can usually determine which lesion is responsible for the hemorrhage, an important consideration in patients who have multiple lesions (i.e., patients with cirrhosis and portal hypertension). The endoscopist can affect therapy in some patients who are bleeding, for example, sclerotherapy of varices and laser coagulation (Larson and Farnell, 1983). It is important to realize that in the majority of patients, endoscopic visualization of the bleeding source does not alter morbidity, mortality, length of hospital stay, or transfusion requirements.

Although endoscopy is excellent in the evaluation of upper gastrointestinal hemorrhage, the role of *colonoscopy* in massive colonic hemorrhage is limited. The presence of stool and large amounts of blood will severely limit visualization of the colon. Flexible sigmoidoscopy has some value in identifying the site of hemorrhage if it is in the rectum as well as documenting the presence of fresh blood originating above this level.

Because barium in the gut interferes with subsequent endoscopy, angiography, and radionuclide procedures, the barium upper GI series should not be used in the initial evaluation of acute hemorrhage. *Double contrast barium studies* are useful if endoscopy has failed and angiography is not attempted because of the cessation of bleeding, if medical therapy stops the hemorrhage and endoscopy is contraindicated, or if endoscopy is negative and angiography is not contemplated.

The barium enema has a limited role in patients with acute massive lower gastrointestinal hemorrhage, most of whom are bleeding from diverticular disease or vascular malformation. Although the double contrast barium enema is superb in the detection of carcinoma and polyps, they only rarely present with massive hemorrhage. Ischemic colitis, usually due to nonocclusive low-flow states, may present as acute lower gastrointestinal hemorrhage. If the patient's history and clinical pattern suggest this diagnosis, a barium enema examination may be the procedure of choice.

Modern angiographic methods have revolutionized the diagnostic and therapeutic approach to acute gastrointestinal hemorrhage. *Arteriography* should be used for patients who continue to bleed despite conservative medical management (Steer and Silen, 1983).

In the upper gastrointestinal tract, arteriography should be used whenever the bleeding is too rapid for efficient endoscopy, if endoscopy is inconclusive, or if a patient is a poor surgical candidate and is so vigorously bleeding as to require therapeutic transcatheter hemostasis. Virtually all major causes of hemorrhage can be identified, and the specific etiology will dictate whether intra-arterial infusion of vasopressin or transcatheter embolization will be employed. The bleeding site is identified in 70 to 95% of patients. The transcatheter hemostatic method will permit time for vascular volume replacement in those patients in whom hemostasis fails or is only temporary. This buys time to get the patient into a more stable condition in preparation for surgery.

Arteriography is the procedure of choice in patients with acute lower gastrointestinal hemorrhage, most of whom are bleeding from colonic diverticula or angiodysplasia. Additionally, arteriography is useful in diverticular hemorrhage because vasopressin infusion and selective embolization have been highly successful in stopping the hemorrhage. In many patients, surgery can be completely avoided. Arteriography will demonstrate small, dilated clusters of arteries and veins, characteristic of angiodysplasia, even if the patient is not actively bleeding.

Arteriography will be positive only if the patient is actively bleeding at the rate of 0.5 to 1 ml/min. If the hemorrhage is slow, intermittent, or has stopped, arteriography will be negative. Some advocate utilizing nuclear techniques to document active bleeding before starting an angiogram, which is more invasive and specific but a less sensitive examination.

Nuclear imaging techniques have been shown to localize occult gastrointestinal bleeding sites, whether active or intermittent, at rates as low as 0.1 ml/min. The major techniques both depend upon recognition of radioactivity in the bowel lumen to indicate hemorrhage. In one technique, a bolus injection of ^{99m}Tc-sulfur colloid, the same radioisotope used for the liver and spleen scan, is administered. Since the reticuloendothelial system rapidly extracts the colloid from blood, extravasated colloid at a bleeding site can be imaged with very high contrast within 10 to 15 minutes. Because of low background activity at this time, small amounts of blood can be seen. This is useful to determine if the patient is actively bleeding because the agent is almost completely removed from the vascular space in 15 minutes. Bleeding must occur within 15 minutes of injection to be detected, however. If the examination is positive, angiography can then be performed with an excellent chance that the bleeding site can be found and therapy effected. The nuclear medicine study should be performed first because it is more sensitive and will save the patient an invasive procedure if no active bleeding can be detected. The principal shortcoming of the procedure is that, like contrast angiography, the patient must be actively bleeding during the relatively short temporal transit of the radioisotope in the blood. Also, areas of bleeding near the liver and spleen may be missed.

Another technique has been developed in which the patient's red blood cells are labeled with ^{99m}Tc pertechnetate. These red blood cells circulate normally, and serial images of the abdomen may reveal focal accumulation of labeled cells in the gut lumen, a pattern fairly easy to differentiate from blood vessels. Serial images can be obtained over a 24-hour period. Thus, intermittent bleeding sites can be located and the geographic movement of extravasated activity can be monitored periodically, allowing more precise anatomical localization of the bleeding site. Because labeled cells in the gut lumen are not resorbed, bleeding that occurs at any time between radiopharmaceutical injection and imaging may be identified. Bleeding that starts and stops over the course of one day may thus be detected. This technique differs from both angiography and ^{99m}Tc sulfur colloid scans in that active bleeding at the time of injection need not be present for detection. The labeled red blood cell technique is less sensitive and requires bleeding rates near 0.5 ml/min, similar to angiography. The sulfur colloid method is superior for active slow bleeders, while the red blood cell method is better for intermittent bleeders.

When bleeding is found, an angiogram can be performed if vasopressin infusion, embolization, or surgery is contemplated.

Chronic gastrointestinal hemorrhage. During the past decade, evaluation of the upper and lower gastrointestinal tracts has been revolutionized by two major developments: the introduction of flexible fiberoptic endoscopy and the widespread use of barium double contrast radiography. Numerous studies have validated the diagnostic accuracy of each procedure and this has inevitably resulted in a dilemma when deciding which study to perform first in a given situation. Some argue that barium studies should be abandoned for the diagnosis of gastric and colonic lesions and that endoscopy and colonoscopy should assume a primary role in evaluating all gastrointestinal lesions. Others have suggested that when a high-quality double contrast study is negative, it is more useful to look elsewhere for the cause of the patient's symptoms. Others believe that colonoscopy and air contrast barium enema, endoscopy and the upper gastrointestinal series are complementary procedures (Gelfund et al., 1984). Clearly, the role and interrelationship of double contrast barium studies and endoscopy are still evolving.

In patients with chronic gastrointestinal hemorrhage who present with guaiac-positive stool or iron deficiency anemia, barium studies should be the initial screening technique. While single contrast barium studies are inaccurate compared to endoscopy and colonoscopy, double contrast techniques significantly increase the yield of both upper and lower gastrointestinal barium studies. Indeed, the yield of barium studies, when well performed, is very similar to that of endoscopy and colonoscopy. In view of the fact that barium studies are one-fourth to one-third the cost of endoscopy and have a very small complication rate, barium studies should be the screening technique.

In patients with chronic lower gastrointestinal blood loss, flexible sigmoidoscopy and air contrast barium enema should be performed. If both these tests are normal, then evaluation can stop. If the air contrast barium enema discloses a polyp, colonscopy can be performed for biopsy and polypectomy.

In patients with suspected upper gastrointestinal hemorrhage, an air contrast study of the stomach, esophagus, and duodenum should be performed first. The small bowel study can be performed if small bowel pathology is suspected. Endoscopy can then be obtained if the clinical suspicion for pathology remains high and these studies are normal.

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